

<p>(51) International Patent Classification ⁶ : H02H 9/02</p>	<p>A2</p>	<p>(11) International Publication Number: WO 98/29931</p> <p>(43) International Publication Date: 9 July 1998 (09.07.98)</p>
<p>(21) International Application Number: PCT/SE97/02131</p> <p>(22) International Filing Date: 17 December 1997 (17.12.97)</p> <p>(30) Priority Data: 9604631-3 17 December 1996 (17.12.96) SE</p> <p>(71) Applicant (for all designated States except US): ASEA BROWN BOVERI AB [SE/SE]; S-721 78 Västerås (SE).</p> <p>(72) Inventors; and</p> <p>(75) Inventors/Applicants (for US only): BERGQVIST, Mikael [SE/SE]; Champinjonvägen 8, S-756 45 Uppsala (SE). BERNHOFF, Hans [SE/SE]; Limsta, Geddeholm, S-720 02 Västerås (SE). EKBERG, Mats [SE/SE]; Brunbjörnsvägen 56, S-722 42 Västerås (SE). FOGELBERG, Thomas [SE/SE]; Bergsmansgatan 12, S-771 35 Ludvika (SE). ISBERG, Jan [SE/SE]; Karlsgatan 27, S-722 14 Västerås (SE). LEUON, Mats [SE/SE]; Hyvrlargatan 5, S-723 35 Västerås (SE). MING, Li [CN/SE]; Högby Skogsväg 1, S-723 41 Västerås (SE). SUNESESSON, Anders [SE/SE]; Hvilans Allé 6, S-232 51 Åkarp (SE). WINDMAR, Dan [SE/SE]; Smedstorp 18, S-744 95 Vittinge (SE). RUSSBERG, Gunnar [SE/SE]; Förvaltargatan 12, S-724 66 Västerås (SE).</p>	<p>(74) Agents: BJERKÉN, Håkan et al.; Bjerkéns Patentbyrå KB, P.O. Box 1274, S-801 37 Gävle (SE).</p> <p>(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, FI (Utility model), GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>In English translation (filed in Swedish). Without international search report and to be republished upon receipt of that report.</i></p>	
<p>(54) Title: A DEVICE AND A METHOD FOR PROTECTING AN OBJECT AGAINST FAULT RELATED OVER-CURRENTS</p>		
<p>(57) Abstract</p> <p>This invention is related to a device and a method in an electric power plant for protection of an object (1) against over-current from a network (3) or another equipment included in the high voltage plant, the device comprising a switching device (4) in a line (2) between the object and the network/equipment. The line (2) between the object and the network/equipment is connected to an arrangement (5) reducing over-currents towards the object (1), said arrangement (5) being actuable for over-current reduction with the assistance of an over-current condition detecting arrangement (11-13) within a time period substantially less than the break-time of the switching device (4). The over-current reducing arrangement (5) comprises a switch means (10) with an electrode gap, which may be imparted electrical conductivity for over-current diversion.</p>		

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LJ	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

A DEVICE AND A METHOD FOR PROTECTING AN OBJECT AGAINST
FAULT RELATED OVERCURRENTS.

5

FIELD OF THE INVENTION AND PRIOR ART

10 This invention is related to a device in an electric power
plant for protection of an electric object from fault-re-
lated over-currents. In addition, the invention includes a
method for protecting the object from over-currents.

15 The electric object in question may be of arbitrary nature
as long as it is contained in an electric power network
and requires protection against fault-related over-cur-
rents, i.e. in practice short-circuit currents. As an
example, it may be mentioned that the object may be formed
20 by an electric apparatus having a magnetic circuit, e.g. a
generator, transformer or motor. Also other objects may be
in question, e.g. power lines and cables, switch gear
equipment etc. The present invention is intended to be
applied in connection with medium and high voltage. Ac-
cording to IEC norm, medium voltage refers to 1-72,5 kV
25 whereas high voltage is >72,5 kV. Thus, transmission, sub-
transmission and distribution levels are included.

In prior power plants of this nature one has resorted to,
for protection of the object in question, a conventional
30 circuit-breaker (switching device) of such a design that
it provides galvanic separation on breaking. Since this
circuit breaker must be designed to be able to break very
high currents and voltages, it will obtain a comparatively
bulky design with large inertia, which reflects itself in
35 a comparatively long break-time. It is pointed out that
the over-current primarily intended is the short-circuit

current occurring in connection with the protected object, for instance as a consequence of faults in the electric insulation system of the protected object. Such faults means that the fault current (short-circuit current) of the external network/equipment will tend to flow through the arc. The result may be a very large breakdown. It may be mentioned that for the Swedish power network, the dimensioning short-circuit current/fault-current is 63 kA. In reality, the short-circuit current may amount to 40-50 kA.

A problem with said circuit-breaker is the long-break time thereof. The dimensioning break-time (IEC-norm) for completely accomplished breaking is 150 milliseconds (ms). It is associated to difficulties to reduce this break-time to less than 50-130 ms depending upon the actual case. The consequence thereof is that when there is a fault in the protected object, a very high current will flow through the same during the entire time required for actuating the circuit-breaker to break. During this time the full fault current of the external power network involves a considerable load on the protected object. In order to avoid damage and complete breakdown with respect to the protected object, one has, according to the prior art, constructed the object so that it manages, without appreciable damage, to be subjected to the short-circuit current/fault current during the break-time of the circuit breaker. It is pointed out that a short-circuit current (fault current) in the protected object may be composed of the own contribution of the object to the fault current and the current addition emanating from the network/equipment. The own contribution of the object to the fault current is not influenced by the functioning of the circuit-breaker but the contribution to the fault current from the network/equipment depends upon the operation of the circuit breaker. The requirement for constructing the protected

object so that it may withstand a high short-circuit current/fault current during a considerable time period means substantial disadvantages in the form of more expensive design and reduced performance.

5

OBJECT OF THE INVENTION

The object of the present invention is to devise ways to design the device and the method so as to achieve better protection for the object and, accordingly, a reduced load on the same, a fact which means that the object itself does not have to be designed to withstand a maximum of short-circuit currents/fault currents during relatively long time periods.

15

SUMMARY OF THE INVENTION

According to the invention, the object indicated above is achieved in that an over-current reducing arrangement, which is actuatable for over-current reduction with assistance of an over-current conditions detecting arrangement, is connected to the electric power plant for protection of the object, that the over-current reducing arrangement comprises an over-current diverter for diverting over-currents to earth or otherwise another unit having a low potential and that the over-current diverter comprises a switch means having an electrode gap which normally is electrically substantially isolating, and means for causing or at least initiating the electrode gap or at least a part thereof to assume electrical conductivity for diverting over-currents via the electrode gap.

Thus, the invention is based upon the principle to utilise a rapidly operating switch means, which without effecting any real breaking of the over-current, nevertheless reduces the same to such an extent that the object under protection will

35

be subjected to substantially reduced strains and accordingly a smaller amount of damages. The reduced over-current/fault-current means, accordingly, that the total energy injection into the protected object will be substantially smaller than in absence of the switch means according to the invention.

The solution according to the invention based upon a switch means according to claim 1 implies a particularly advantageous fulfilling of demands which may be set up in order to achieve a satisfactory protection function. Thus, a very rapid triggering may be achieved by the switch means so that occurring fault-related over-currents with a very small delay in time will be diverted via the switch means as soon as the electrode gap has adopted an electrically conductive condition. It is pointed out that the term "triggering" in this connection means bringing the switch means into an electrically conducting state. By means of the arrangement of the switch means, said switch means may easily be dimensioned to be able to conduct very large currents. In order to obtain a satisfactory protection function it is, namely, desirable that the current conducting channel, which is established through the switch means, has a very low resistance. This means the largest possible strain-relieving of the object, which is to be protected from fault-currents. Besides, a switch means according to claim 1 may with a small effort be caused to function with a particularly high triggering safety. The triggering must not, in order to divert occurring fault-currents as soon as possible, therefore, fail in a critical situation. The switch means according to the invention gives on the other hand rise to the possibility to dimensioning in order to achieve a very high electric strength in a non-triggered condition. The probability for a spontaneous breakthrough is thus to be at a minimum. The means for causing or at least initiating the electrode gap to assume electrical conductivity are

according to the invention preferably arranged to supply triggering energy to the electrode gap in the form of radiant energy. It is especially preferred to thereby use at least one laser for triggering.

5

Preferable developments with respect to a.o. the means for supplying radiant energy to the electrode gap are defined in the enclosed claims. According to one embodiment, the radiant energy is supplied to the electrode gap in two or more spots or areas for the purpose of achieving the highest possible certainty with regard to bringing the electrode gap to assume an electrically conducting state. According to one alternative the energy supply members may be designed to supply the radiant energy along an elongated area in the conduction path which is aimed at between the electrodes. According to an optimal embodiment this elongated area may, entirely or substantially entirely, bridge the gap between the electrodes. Although it is possible, in a case with two or more spots or areas for radiation supply, that these spots or areas are applied successively corresponding to the propagation with respect to the electrical conduction path between the electrodes in such a way that the spots or areas are successively applied with a time delay, it is, according to the invention, normally preferred to apply these spots or areas substantially simultaneously.

25

Furthermore, the means for supply of triggering energy may according to the invention be adapted to apply the radiant energy in a volume having a tubular shape. This is particularly preferable when one of the electrodes comprises an opening, through which the radiant energy is supplied, and when the radiant energy supplied in a tubular volume is applied relatively close to the electrode provided with an opening.

35

According to an alternative embodiment, the energy supply means may be designed to supply the radiant energy in a plurality of substantially parallel, elongated areas extending between the electrodes.

5

The radiant energy may also be supplied to the electrode gap transversely relative to an axis of the electrodes in one or more spots located between the electrodes.

10 Further advantages and features of the invention, particularly with respect to the method according to the invention, appear from the following description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

15

With reference to the enclosed drawings, a more specific description of an embodiment example of the invention follows hereinafter.

20 In the drawings:

Fig 1 is a purely diagrammatical view illustrating the basic aspect behind the solution according to the invention,

25

Figs 2a-2d are diagrams illustrating in a diagrammatical form and in a comparative way fault current developments and the energy development with and without the protection device according to the invention;

30

Fig 3 is a diagrammatical view illustrating a conceivable design of a device according to the invention;

35

- Fig 4 is a diagrammatical, detailed view illustrating a possible design of the over-current reducing arrangement
- 5 Figs 5-7 are views similar to Fig 4 of different variants,
- Fig 8 is a diagrammatical view illustrating an optical system for energy supply to the electrode gap;
- 10 Fig 9 is a view illustrating an alternative optical system placed at the side of one of the electrodes;
- 15 Fig 10 is a further alternative for an optical system arranged to supply the radiant energy around one of the electrodes and co-axially relative thereto without need for an opening in one of the electrodes;
- 20 Fig 11 is a view of an optical system based upon use of optical fibres;
- Fig 12 is a principle view illustrating refraction of light emanating from a point source by means of a refractive axicone;
- 25 Fig 13 is a view similar to fig 16 but showing the action of the axicone on a collimated laser beam;
- 30 Fig 14 is a view illustrating the function of a refractive axicone for generation of an elongated focal area between the electrodes;
- Fig 15 is a diagram illustrating the power density along the focal area in fig 18;
- 35

- Fig 16 is a view similar to fig 18 but illustrating the use of a diffraction optical component;
- 5 Fig 17 is a view illustrating focusing in an elongated area by means of a reflective axicone;
- Fig 18 is a view illustrating use of a diffractive axicone (a kinoform) capable of generating focal areas having different geometrical shapes;
- 10 Fig 19 is a diagrammatical view illustrating the device according to the invention applied in an electric power plant comprising a generator, a transformer and an electric power network coupled thereto;
- 15 Fig 20 is a view illustrating how energy may be supplied to the electrode gap transversely relative to an axis common to the electrodes, fig 20a illustrating radiant energy being supplied in a single spot or area whereas three such spots or areas occur in fig 20b;
- 20
- Fig 21a and b are views illustrating how the radiant energy may be supplied such that several substantially parallel and electrically conducting channels are formed between the electrodes;
- 25
- Fig 22 is a sideview illustrating an embodiment somewhat similar to the one in fig 10, it being apparent from
- 30
- Fig 23 that a plurality of individual kinoforms (diffractive optical elements) are arranged around one of the electrodes.
- 35

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

5 An electric power plant comprising a protected object 1 is shown in Fig 1. This object could for instance consist of a generator. This object is connected, via a line 2, to an external distribution network 3. Instead of such a network, the unit denoted 3 could be formed by some other equipment contained in the electric power plant. The
10 electric power plant involved is conceived to be of such a nature that it is the object 1 itself which primarily is intended to be protected against fault currents from the network/equipment 3 when there occurs a fault in the object 1 giving rise to a fault current from the net-
15 work/equipment 3 towards the object 1 so that the fault current will flow through the object. Said fault may consist in a short-circuit having been formed in the object 1. A short-circuit is a conduction path, which is not intended, between two or more points. The short-circuit may
20 for instance consist of an arc. This short-circuit and the resulting violent current flow may involve considerable damages and even a total break-down of the object 1.

It is already pointed out that with at least some types of
25 protected electrical objects 1, short-circuit currents/fault currents harmful to the object in question may flow from the protected object towards the network/equipment 3. Within the scope of the invention, it is intended to be used for protection purposes not only for
30 protection of the object from externally emanating fault currents flowing towards the object but also from internal fault currents in the object flowing in the opposite direction. This will be discussed in more detail in the following.

35

In the following, the designation 3 will, to simplify the description, always be mentioned as consisting of an external electric power network. However, it should be kept in mind that some other equipment may be involved instead of such a network, as long as said equipment causes violent current flows through the object 1 when there is a fault.

A conventional circuit breaker 4 is arranged in the line 2 between the object 1 and the network 3. This circuit breaker comprises at least one own sensor for sensing circumstances indicative of the fact that there is an overcurrent flowing in the line 2. Such circumstances may be currents/voltages but also other indicating that a fault is at hand. For instance, the sensor may be an arc sensor or a sensor recording short circuit sound etc. When the sensor indicates that the overcurrent is over a certain level, the circuit breaker 4 is activated for breaking of the connection between the object 1 and the network 3. The circuit breaker 4 must, however, break the total short circuit current/fault current. Thus, the circuit breaker must be designed to fulfil highly placed requirements, which in practice means that it will operate relatively slowly. In Fig 2a it is illustrated in a current/time-diagram that when a fault, for instance a short circuit in the object 1, occurs at the time t_{fault} , the fault current in the line denoted 2 in Fig 1 rapidly assumes the magnitude i_1 . This fault current i_1 is broken by means of the circuit breaker 4 at t_1 , which is at least within 150 ms after t_{fault} . Fig 2d illustrates the diagram $i^2 \cdot t$ and, accordingly, the energy developed in the protected object 1 as a consequence of the short circuit therein. The energy injection into the object occurring as a consequence of the short-circuit current is, accordingly, represented by the total area of the outer rectangle in Fig 2d.

It is in this connection pointed out that the fault current in Figs 2a-c and the currents in Fig 2d represent the envelope of the extreme value. Only one polarity has been drawn out in the diagram for the sake of simplicity.

5

The circuit breaker 4 is of such a design that it establishes galvanic separation by separation of metallic contacts. Accordingly, the circuit breaker 4 comprises, as a rule, required auxiliary equipment for arc extinguishing.

10

According to the invention the line 2 between the object 1 and the switching device 4 is connected to an arrangement reducing overcurrents towards the apparatus 1 and generally denoted 5. The arrangement is actuatable for overcurrent reduction with the assistance of an overcurrent conditions detecting arrangement within a time period substantially less than the break time of the circuit breaker 4. This arrangement 5 is, accordingly, designed such that it does not have to establish any galvanic separation.

15

20

Therefore, conditions are created to very rapidly establish a current reduction without having to accomplish any total elimination of the current flowing from the network 3 towards the protected object 1. Fig 2b illustrates in contrast to the case according to Fig 2a that the overcurrent reducing arrangement 5 according to the invention is activated upon occurrence of a short circuit current at the time t_{fault} for overcurrent reduction to the level i_2 at the time t_2 . The time interval $t_{\text{fault}} - t_2$ represents, accordingly, the reaction time of the overcurrent reducing arrangement 5. Since the task of the arrangement 5 is not to break but only reduce the fault current, the arrangement may be caused to react extremely rapidly, which will be discussed more closely thereunder. As an example, it may be mentioned that current reduction from the level i_1 to the level i_2 is intended to be accomplished within one or a few ms after unacceptable overcurrent conditions hav-

25

30

35

ing been detected. It is then aimed at to accomplish the current reduction in a shorter time than 1 ms, and preferably more rapidly than 1 microsecond.

5 As appears from Fig 1, the device comprises a further breaker generally denoted 6 and arranged in the line 2 between the circuit breaker 4 and the object 1. This further breaker is designed to break a lower voltage and current than the circuit breaker 4 and may, as a consequence
10 thereof, be designed to operate with shorter break times than the circuit breaker. The further breaker 6 is arranged to break not until after the overcurrent from the network 3 towards the object 1 has been reduced by means of the overcurrent reducing arrangement 5 but substantially
15 earlier than the circuit breaker 4. From that stated, it appears that the further breaker 6 should be coupled to the line 2 in such a way that it is the current reduced by means of the overcurrent reducing arrangement 5 which will flow through the further breaker and which, according
20 accordingly, is to be broken by means thereof.

Fig 2b illustrates the action of the further breaker 6. This breaker is, more specifically, designed to break at the time t_3 , which means that the duration of the current
25 i_2 reduced by means of the overcurrent reducing arrangement 5 is substantially delimited, namely to the time period t_2 - t_3 . The consequence is that the energy injection into the protected object 1 caused by a fault current from the network 3 is represented by the surfaces marked with
30 oblique lines in Fig 2d. It appears that a drastic reduction of the energy injection is achieved. In this connection it is pointed out that since, according to a specific model, the energy increases with the square of the current, a reduction to one half of the current reduces the
35 energy injection to a fourth. It is illustrated in Fig 2c how the fault current will flow through the arrangement 5.

The dimensioning of the arrangement 5 and the further breaker 6 is conceived to be carried out such that the arrangement 5 reduces the fault current and the voltage to be broken by means of the further breaker 6 to substantially lower levels. A realistic break time as to the further breaker 6 is 1 ms. However, the dimensioning should be made such that the breaker 6 is caused to break not until after the arrangement 5 having reduced the current flowing through the breaker 6 to at least a substantial degree.

It is illustrated in more detail in Fig 3 how the device may be realised. It is then pointed out that the invention is applicable in direct current (also HVDC = High Voltage Direct Current) and alternating-current connections. In the latter case, the line denoted 2 may be considered to form one of the phases in a multiphase alternating-current system. However, it should be kept in mind that the device according to the invention may be realised so that either all phases are subjected to the protection function according to the invention in case of a detected fault or that only that phase or those phases where a fault current occurs are subjected to current reduction.

25

It appears from Fig 3 that the overcurrent reducing arrangement generally denoted 5 comprises an overcurrent diverter 7 for diverting overcurrents to earth 8 or otherwise another unit having a lower potential than the network 3. Thus, the overcurrent diverter may be considered as forming a current divider which rapidly establishes a short circuit to earth or otherwise a low potential 8 for the purpose of diverting at least a substantial part of the current flowing in the line 2 so that said current does not reach the object 1 to be protected. If there is a serious fault in the object 1, for instance a short cir-

cuit, which is of the same magnitude as the short circuit that the overcurrent diverter 7 is capable of establishing, it may be said that generally speaking a reduction to one half of the current flowing to the object 1 from the network 3 is achieved as a consequence of the overcurrent diverter 7 in case the fault is close to the latter. In comparison with Fig 2b, it appears, accordingly, that the current level i_2 illustrated therein and being indicated to amount to approximately half of i_1 may be said to represent the worst occurring case. Under normal conditions, the purpose is that the overcurrent diverter 7 should be able to establish a short circuit having a better conductivity than the one corresponding to the short circuit fault in the object 1 to be protected so that accordingly a main part of the fault current is diverted to earth or otherwise a lower potential via the overcurrent diverter 7. It appears from this that, accordingly, in a normal fault case, the energy injection into the object 1 in case of a fault becomes substantially smaller than that which is indicated in Fig 2d as a consequence of lower current level i_2 as well as shorter time span t_2 - t_3 . It should be obvious that a certain protection is obtained also when a short-circuit, which has been established, has a somewhat lower conductivity than the one corresponding to the short-circuit fault in the object 1 to be protected.

It has been pointed out that the notation 8 not only includes earth but another unit with a lower potential than the network/equipment 3. It is thereby to be noted that the unit 8 possibly could be formed by another power network or another equipment included in the electric power plant, said equipment having a lower level of voltage than the one which is effective for the network/equipment 3, to which the object 1, which is to be protected, is connected.

The over-current diverter 7 comprises switch means coupled between earth 8 or said lower potential and the line 2 between the object 1 and the network 3. This switch means comprises a control member 9 and a switch member 10. This switch member is arranged to be open in a normal state, i.e. insulating in relation to earth. The switch member 10 may however be brought into a conductive state via the control member 9 in a very short time in order to establish current reduction by diversion to earth.

Fig 3 illustrates that an overcurrent conditions detecting arrangement may comprise at least one and preferably several sensors 11-13 suitable for detecting such overcurrent situations requiring activation of the protection function. As also appears from Fig 3, these sensors may include the sensor denoted 13 located in the object 1 or in its vicinity. Furthermore, the detector arrangement comprises a sensor 11 adapted to sense overcurrent conditions in the line 2 upstreams of the connection of the overcurrent reducing arrangement 5 and the line 2. As is also explained in the following, it is suitable that a further sensor 12 is provided to sense the current flowing in the line 2 towards the object 1 to be protected, i.e. the current which has been reduced by means of the overcurrent reducing arrangement 5. In addition, it is pointed out that the sensor 12, as well as possibly the sensor 13, is capable of sensing the current flowing in the line 2 in a direction away from the object 1, for instance in cases where energy magnetically stored in the object 1 gives rise to a current directed away from the object 1.

It is pointed out that the sensors 11-13 do not necessarily have to be constituted by only current and/or voltage sensing sensors. Within the scope of the invention, the sensors may be of such nature that they generally speaking may sense any conditions indicative of the occurrence of a

fault of the nature requiring initiation of a protection function.

5 In cases where such a fault occurs that the fault current will flow in a direction away from the object 1, the device is designed such that the control unit 14 thereof will control the further breaker 6 to closing, in case it would have been open, and, in addition, the overcurrent reducing arrangement 5 is activated such that the short
10 circuit current may be diverted by means of the same. When, for example, the object 1 is conceived to consist of a transformer, the function on occurrence of a short circuit therein could be such that the short circuit first gives rise to a violent flow of current into the trans-
15 former, which is detected and gives rise to activation of the arrangement 5 for the purpose of current diversion. When the current flowing towards the transformer 1 has been reduced in a required degree, the breaker 6 is caused to break, but, controlled by means of the control unit 14,
20 not earlier than leaving time for the energy, in occurring cases, magnetically stored in the transformer 1 to flow away from the transformer 1 and be diverted via the arrangement 5.

25 Furthermore, the device comprises a control unit generally denoted 14. This is connected to the sensors 11-13, to the overcurrent reducing arrangement 5 and to the further breaker 6. The operation is such that when the control unit 14 via one or more of the sensors 11-13 receives sig-
30 nals indicating occurrence of unacceptable fault currents towards the object 1, the overcurrent reducing arrangement 5 is immediately controlled to rapidly provide the required current reduction. The control unit 14 may be arranged such that when the sensor 12 has sensed that the
35 current or voltage has been reduced to a sufficient degree, it controls the breaker 6 to obtain operation

thereof for breaking when the overcurrent is below a pre-determined level. Such a design ensures that the breaker 6 is not caused to break until the current really has been reduced to such a degree that the breaker 6 is not given the task to break such a high current that it is not adequately dimensioned for that purpose. However, the embodiment may alternatively also be such that the breaker 6 is controlled to break a certain predetermined time after the overcurrent reducing arrangement having been controlled to carry out current reduction.

The circuit breaker 4 may comprise a detector arrangement of its own for detection of overcurrent situations or otherwise the circuit breaker may be controlled via the control unit 14 based upon information from the same sensors 11-13 also controlling the operation of the overcurrent reducing arrangement.

It is illustrated in Fig 3 that the further breaker 6 comprises a switch 15 having metallic contacts. This switch 15 is operable between breaking and closing positions by means of an operating member 16, which in turn is controlled by the control unit 14. A shunt line 17 is connected in parallel over this switch 15, said shunt line comprising one or more components 18 intended to avoid arcs on separation of the contacts of the switch 15 by causing the shunt line 17 to take over the current conduction from the contacts. These components are designed so that they may break or restrict the current. Thus, the purpose is that the components 18 normally should keep the conduction path in the shunt line 17 interrupted but close the shunt line when the switch 15 is to be opened so that accordingly the current is shunted past the switch 15 and in that way arcs do not occur or possibly occurring arcs are efficiently extinguished. The components 18 comprise one or more associated control members 19 connected to the

control unit 14 for control purposes. According to one embodiment of the invention, said components 18 are controllable semiconductor components, for instance GTO thyristors, having necessary over-voltage arresters 30.

5

A disconnecter 20 for galvanic separation in the current conduction path created by means of the shunt line 17 to the object 1 to be protected is arranged in series with said one or more components 18. This disconnecter 20 is
10 via an operating member 21 controlled by the control unit 14. The disconnecter 20 is illustrated in Fig 3 as being placed in the shunt line 17 itself. This is of course not necessary. The disconnecter 20 could also be placed in the
15 line 2 as long as it ensures real galvanic separation, by series coupling with said one or more components 18, in the conduction path established by means of said series coupling so that accordingly there is not any possibility for current to flow through the components 18.

20 The device as it has been described so far operates in the following manner: In absence of a fault, the circuit breaker 4 is closed just like the switch 15 of the further breaker 6. The components 18 in the shunt line 17 are in a non-conducting state. The disconnecter 20 is closed. Fi-
25 nally, the switch means 10 of the overcurrent reducing arrangement 5 is open, i.e. it is in a non-conducting state. In this situation the switch means 10 must, of course, have an adequate electrical strength so that it is not inadvertently brought into a conducting state. Overvoltage
30 conditions occurring in the line 2 as a consequence of atmospheric (lightning stroke) circumstances or coupling measures may, accordingly, not involve the voltage strength of the switch means 10 in its non-conducting state to be exceeded. For this purpose it is suitable to
35 couple at least one over-voltage arrester 22 in parallel with the switch means 10. In the example such over-voltage

arresters are illustrated on both sides of the switch means 10. Accordingly, the over-voltage arresters have the purpose to divert such overvoltages which otherwise could involve a risk for inadvertent breakthrough in the switch means 10.

The over-voltage diverters 22 are illustrated in Fig 3 to be connected to the line 2 itself on either sides of the connection of the switch means 10 to the line. It is in principle desirable that at least one over-voltage diverter has its connection as close as possible upstreams in relation to the switch means 10. The over-current diverters 22 could instead, which is indicated in Fig. 3 with the dotted lines 26 be connected to the branch line forming electric connection between the switch means 10 and the line 2. Such a construction enables integration of the switch means 10 and at least one over-voltage diverter 22 to one single electric apparatus, which apparatus may be brought in electric conducting connection with the line 2 via one single connection.

When an over-current state has been registered by means of some of the sensors 11-13 or the own sensor (it is of course realized that information from the own sensor of the circuit breaker 4 may be used as a basis for control of the over-current reducing arrangement 5 according to the invention) of the circuit breaker 4 and this over-current state is of such magnitude that a serious fault of the object 1 is expected to be at hand, a breaking operation is initiated as far as the circuit breaker 4 is concerned. In addition, the control unit 14 controls the over-current reducing arrangement 5 to effect such reduction, and this more specifically by bringing, via the control member 9, the switch means 10 into an electrically conducting state. As described before, this may occur very rapidly, i.e. in a fraction of the time required for breaking by means of the circuit breaker 4, for what rea-

son the object 1 to be protected immediately is liberated from the full short-circuit current from the network 3 as a consequence of the switch means 10 diverting at least an essential part, and in practice the main part, of the current to earth or otherwise a lower potential. As soon as the current, which flows towards the object 1 via the further breaker 6, has been reduced in a required degree, which can be established on a pure time basis by a time difference between activation of the switch means 10 and operation of the breaker 6, or by sensing of the current flowing in the line 2 by means of, for instance, the sensor 12, the operating member 16 of the switch 15 is, via the control unit 14, controlled to open the contacts of the switch 15. For extinguishing or avoiding arcs, the components 18, e.g. GTO thyristors or gas switches, are via the control members 19 controlled to establish conductivity of the shunt line 17. When the switch 15 has been opened and, thus, provided galvanic separation, the component 18 is again controlled to bring the shunt line 17 into a non-conducting state. In that way the current from the network 3 towards the object 1 has been efficiently cut off. After having brought the shunt line 17 into a non-conducting state, galvanic separation may, in addition, be effected by means of the disconnecter 20 by controlling the operating member 21 thereof from the control unit 14. When all these incidents have occurred, breaking by means of the circuit breaker 4 occurs as a last incident. It is important to note that the over-current reducing arrangement 5 as well as the further breaker 6 according to a first embodiment can be operated repeatedly. Thus, when it has been established by means of the sensors 11-13 that the circuit breaker 4 has been brought to cut off, the switch means 10 is reset to a non-conducting state and the switch 15 and the disconnecter 20 are again closed so that when the circuit breaker 4 next time closes, the protection device is completely operable.

According to another embodiment, it is, however, contemplated that the over-current reducing arrangement 5 may require exchange of one or more parts in order to operate again.

5

It is pointed out that according to an alternative embodiment of the invention, the component or components 18 could be brought into a conducting state as soon as the over-current reducing arrangement 5 has been brought into
10 a closing state and this independently of whether the switch 15 possibly is not opened thereafter. The control of the components 18 could then, as described before, occur via the control unit 14 or, alternatively, by means of a control function involving a slavish following of the
15 closing of the arrangement 5.

Fig 4 illustrates a first embodiment of the over-current reducing arrangement 5 with switch means denoted 10a. The switch means 10a has electrodes 23 and a gap 24 prevailing
20 between these electrodes. The switch means as it has been described so far has means 25a in order to trigger the electrode gap 24 to form an electrically conducting path between the electrodes. A control member 9a is arranged to control the operation of the members 25a via the control unit 14a.
25 The means 25a are in the example arranged for causing or at least initiating the electrode gap to assume electrical conductivity by means of causing the gap or part thereof to form a plasma. It is thereby essential that the means 25a are capable of realising a very rapid supply of triggering
30 energy to the electrode gap. It is thereby preferred that the triggering energy is supplied in the form of radiative energy, which in turn is capable of effecting ionising/initiating of plasma in the electrode gap.

35 The means 25a comprises according to a preferred embodiment of the invention at least one laser, which by means of

energy supply to the electrode gap causes ionising/forming of plasma in at least a part of the electrode gap.

It is preferred in accordance with the invention to supply, with the aid of one or several lasers or other means 25a, energy to the electrode gap 24 in such a way that the complete electrode gap will be ionised and brought to the form of a plasma respectively, approximately momentarily in a way that also the complete gap 24 immediately is brought to electrical conductivity. In order to spare with and optimize the use of the (normally) restricted available laser energy/-effect, the means 25a may, in application of the invention, be arranged so that they can provide ionization/plasma formation in only one or more parts of the gap 24. In the embodiment according to fig 4, it is illustrated that the means 25a supply the radiant energy in one single spot or area 28. As will be described later, the invention also comprises application of the radiant energy in a plurality of spots or areas in the electrode gap, including also on one of or both of the electrodes, or in one or more rodlike areas extending continuously or substantially continuously between the electrodes.

By connecting the switch means 10a between the line 2 and earth 8 (or another unit with lower potential) as is diagrammatically indicated in Fig 4, i.e. with one of the electrodes 23 connected to the line 2 and the other electrode connected to earth 8, there will be a voltage difference between the electrodes causing an electric field. The electric field in the gap 24 is intended to be utilised in order to convey or cause an electric breakdown between the electrodes as soon as the means 25a have been controlled to triggering, i.e. have given rise to ionising/forming of plasma in one or more parts of the electrode gap. The established ionising/forming of plasma will be driven by the electric field to shunt the gap between the electrodes in order to in

this way give rise to a low-resistant electrical conductive channel, i.e. an arc between the electrodes 23. It is pointed out that the invention is not intended to be restricted to use in connection with occurrence of such an electric field. Thus, the intention is that the means 25a should be capable of establishing electrical conduction between the electrodes also without such a field.

Due to the demand on the switch means 10a to close very rapidly for current diversion, it is thus desirable when only a restricted part, e. g. a spot like part of the gap is ionised that the switch means is dimensioned in such a way that the strength of the electric field in the gap 24 will be sufficiently high for safe closing. It is however on the other hand a desire that the switch means 10a should have a very high electric strength against breakdowns between electrodes in its isolating rest position. The strength of the electric field in the gap 24 should therefore be proportionally low. This will on the other hand reduce the speed, with which the switch means may be caused to establish the current diverting arc between the electrodes. In order to achieve an advantageous relation between the desire for a safe triggering of the switch means and on the other hand high electric strength against undesired triggering, it is according to the invention preferred that the switch means is formed in such a way that regarding its complete operational environment the electric field in the gap 24 has a field strength which is not more than 30% of the field strength at which a spontaneous breakdown normally takes place, when the gap forms electric isolation. This causes a proportionally low probability of a spontaneous breakdown,

The strength of the electric field in the electrode gap 24 in its isolating state is suitably not more than 20% and preferably not more than 10% of the field strength at which

a spontaneous breakdown normally takes place. In order to on the other hand achieve an electric field in the electrode gap 24, which promotes forming of an arc at initiation of ionising/forming of plasma in a part of the electrode gap in a relatively rapid way, it is preferred that the strength in the electric field is at least 0,1% and suitably at least 1% (E_4), and preferably at least 5% of the field strength, at which a spontaneous breakdown normally takes place.

10 The electrode gap 24 is, as may be seen in Fig. 4, enclosed in a suitable casing 32. A vacuum as well as a suitable medium in the form of gas or even fluid may for this purpose be present in the gap 24. In the case of a gas/fluid the medium in the gap is intended to be formed in such a way that it might be ionised and brought to plasma by triggering. It would in such a case be suitable to initiate ionisation/forming of plasma in the gap 24 at a point somewhere between the electrodes 23. It is however in Fig 4 illustrated the conceived case where there either is a vacuum or a suitable medium in the gap 24. It is then preferred that initiation of closing takes place by way of making the laser 25a, which is illustrated in Fig 4, to focus the emitted radiative energy in at least one area 28 on or in the vicinity of one of the electrodes via a suitable optical system 27. This implies that the electrode will operate as an electron and ion emitter for establishing an ionised environment/a plasma in the electrode gap 24 in such a way that thus an arc will be formed between the electrodes. One of the electrodes 23 may according to Fig 4 have an opening 29, through which the laser 25a is arranged to emit the radiative energy to the area 28 with support of the optical system 27.

Fig 5 illustrates a variant 10b of the switch means, where instead the system laser 25b/optics 27b focus the radiative energy in a triggering area 28b, which is situated between

the electrodes and in a medium between these electrodes. Plasma is accordingly, on triggering, intended to be developed from this area to bridging of the electrodes.

5 The variant 10c of the switch means in Fig 6 differs from the one in Fig 4 in the way that auxiliary electrodes 31 have been arranged between the electrodes 23c in this case, said auxiliary electrodes suitably being annular in a way that the beam emitted by the laser 25c may pass through the
10 auxiliary electrodes 31. These electrodes are intended to operate for smoothing the electric field between the electrodes 23c and may be isolated from each other, i.e. they may be on a floating potential. The auxiliary electrodes result in improved safety against a spontaneous breakthrough,
15 reduced dimensions of the switch means and a reduced sensitivity to the effect of external fields. The auxiliary electrodes may also be exposed to the laser beam/laser pulse and be made to emit free charges, which further promote the triggering capability.

20

Fig 7 illustrates a variant 10d of the switch means with the change that the electrodes 31d are added also here, in similarity to what has been described with the reference to Fig 6.

25

In order to achieve the above discussed relations regarding the field strength conditions between the electrodes 23 in the isolating state of the switch means, the characteristics of the switch means must of course be adequately adapted to
30 the intended use, i.e. the voltage conditions which will arise over the electrodes 23. The constructive steps available regard of course forming of the electrodes, distance between the electrodes, the medium between the electrodes and the presence of possible further field
35 affecting components between the electrodes.

Diffractive optical elements may be used with the invention. Diffractive optical elements are elements, in which the wave fronts of the light, which wave fronts determine the propagation of the light, are formed by means of diffraction rather than refraction. A particular type of diffractive optics modulates only the phase of the light and not the amplitude, for what reason components of this type has a very high transmittance. Pure phase modulation may be achieved by providing the surface of the optical component with a relief structure, where the relief height should be of the same order as the wavelength in order to achieve an optimum function of the component. An alternative way of achieving phase modulation is to modulate the refractive index of the optical element, which modulation is rather difficult. Diffractive optical elements may be manufactured by means of holographic technique, which does not admit that arbitrary functions may be realized. A more flexible manufacturing mode is computer generation, in which mode the optical function may be calculated in a computer. Entirely arbitrary optical functions may then, in principle, be realized, said functions often being impossible to obtain by means of conventional refractive and reflective optics. The resulting face surface is thereafter transferred to a relief, e.g. by means of electron beam lithography or optical lithography, both of which are well known within the semi-conductor art. Such dator generated, phase controlling surface relief components are often called kinoforms. A well-known example is the Fresnell lens. This lens may, as all diffractive optics, be designed as a binary structure consisting of only two relief levels, or as a multilevel relief providing a substantially improved diffraction efficiency (functional efficiency of the optical element).

Fig 8 illustrates an embodiment based upon an optical system 27e comprising a lens system 35, via which arriving laser pulses are conveyed to a diffractive optical phase element

36, a kinoform. This element is designed to have a plurality of focal points or spots 28e generated starting from a single incoming laser pulse. These focal spots 28e are distributed along the axis of symmetry between the electrodes 23e. As a consequence of the focal spot 28e being distributed along a line between the electrodes 23e, a more safe establishment of an electrical conduction path between the electrodes is achieved, meaning as high a probability for triggering as possible at a voltage/electrical field strength as low as possible and with a time delay as short as possible.

The kinoform 36 is low absorbing and may, accordingly, resist extremely high optical energy densities. The kinoform is, accordingly, produced from a dielectrical material so that it will not disturb the electrical field between the electrodes in any serious degree.

In the embodiment according to fig 8, the radiant energy is supplied through an opening 29e in one of the electrodes as before. Fig 9 illustrates a variant where, generally speaking, the only difference as compared to the embodiment according to fig 8 is that the diffractive optical element (kinoform 36f) is placed radially externally of one of the electrodes 23f. The optical element 36f is as before designed to deflect the laser light and focus the same in a number of spots or points distributed along the intended electrical conduction path between the electrodes. The bunches of beams forming the spots 28f have each their own deflection angle. Thus, the bunches of beams have to travel different distances to the respective spots 28f. The advantage in locating the kinoform 36f according to fig 9 at the side of one of the electrodes is that the kinoform will be located sidewardly of the strongest electrical field so that the field disturbance will be at a minimum. The

electrode design is also simplified since no opening for the laser light is required.

Fig 10 illustrates an embodiment where a laser 25g supplies the laser radiation via an optical system 27g symmetrically in a number of focal spots or points 28g distributed along the length of the electrode gap without requiring any opening in the electrodes 23g. The optical system 27g comprises a prisma or beam divider 37 arranged to deflect the laser beam around the adjacent electrode 23g. Around this electrode 23g there is provided one or preferably more kinoforms 36g (diffractive optical elements) designed to focus, possibly by means of further lenses, the laser beam in the desired focal spot 28g so that plasma formations are generated in these spots.

Fig 11 illustrates a variant where a laser beam is conveyed by means of an optical system 27h comprising optical fibres 38 for formation of focal spots 28h located at various places between the electrodes 23h. The optical fibres 38 may be arranged to emit the light via lenses 39.

Fig 12 illustrates the basic principle of a conical lens, a so-called axicone. The definition of such an axicone may be said to be every optical element having symmetry with regard to rotation and being capable of deflection of light by means of a refraction, reflection, diffraction or combinations thereof from a point source on the axis of symmetry of the element in such a way that the light intersects this axis of symmetry not in a single point as would be the case with a conventional spherical lens, but along a continuous line of points or spots along a substantial extent of this axis.

It is illustrated in fig 13 that collimated (non-divergent) light beams are deflected the same angle by the axicone. As

a consequence of the symmetry as far as rotation is concerned, each beam will cross the axis of symmetry in some point.

5 It appears from fig 14 that the light may be focused in an elongated focal area 28i located between the electrodes 23i by means of an axicone 36i. This elongated focal area may according to one embodiment of the invention extend continuously all the way between the electrodes but could
10 also adopt only a part of the gap therebetween. Fig 15 illustrates how the intensity is related to the distance between the electrodes. The full line curve illustrates the intensity distribution on illumination with the light beam which originally had a Gaussic intensity distribution
15 whereas the dashed line curve illustrates the intensity distribution on illumination with a constant intensity distribution. For the rest, it is pointed out that the invention is not only restricted to such axicones which are purely linearly conical. Thus, axicones, the mantle surface
20 of which deviate from the linear cone, which will have a direct influence on the focal intensity distribution, are included within the scope of the invention.

Fig 16 illustrates that a similar result as the one in fig
25 14 as far as the focal area 28k is concerned may be achieved by means of a diffraction optical element 36k, a kinoform.

Fig 17 illustrates that an elongated focal area 28m in the gap between electrodes 23m may be achieved by means of an
30 axicone, more specifically a reflective axicone.

Fig 18 illustrates an embodiment where a particularly designed diffractive axicone 36n, a kinoform, has been designed to provide focal areas 28n and 28n' respectively
35 having different shapes. In the example it is illustrated that the focal area 28n is elongated and arranged on the

axis of symmetry of the axicone 36n and the electrodes. In contrast, the focal area 28n' has, as is indicated to the left in fig 18, obtained a tubular shape in cross-section. This tubular shape is advantageous most closely to an electrode 23n provided with an opening 29n since the periphery of the tubular focal area 28n' will be located relatively close to the electrode 29n provided with an opening. Both focal areas 28n and 28n' have, in fig 18, a substantially constant intensity along the axis of symmetry but perpendicular to this axis the intensity distribution, as far as the focal area 28n is concerned, is substantially Gauss-shaped or shaped in accordance with the Bessel function.

15 An advantage with an entirely or substantially conical or diffractive, co-axially focusing component as for instance in figs 8, 9, 10, 14, 16, 18 is that along the efficient direction of propagation of the radiant energy, said direction of propagation being a straight line, the plasma volume first formed, which occurs most closely to the electrode, at which the radiant energy is supplied, will not shield, reflect or to a serious degree affect the radiant energy focused in spots/areas being located further away from the supply electrode. This "shadow effect" from the first formed plasma volumes could otherwise have hindered the radiant energy to efficiently reach later foci. This is a consequence of a plasma having the ability to be able to reflect or absorb radiant energy.

30 Fig 19 illustrates an embodiment where a generator 1b is connected to a power network 3a via a transformer 1a. The objects which are to be protected are therefore represented by the transformer 1a and the generator 1b. The over-current reducing arrangement 5a and the further breaker 6a as well as the ordinary circuit breaker 4a are apparently arranged in resemblance with what is evident from Fig 1 in the case

that the object 1 in Fig 1 is conceived to form the object 1a according to Fig 19. It is therefore in this regard referred to the descriptions in connection to Fig 1. The same is true for the protection operation of the over-current reducing arrangement 5c and the further breaker 6c in relation to the generator 1b. The generator 1b should therefore in this case be equivalent to the object 1 in Fig 1 while the transformer 1a should be equivalent to the equipment 3 in Fig 1. The over-current reducing arrangement 5c and the further breaker 6c will therefore in combination with the conventional circuit breaker 4b be able to protect the generator 1b against a violent current flow in the direction from the transformer 1a.

Fig 19 also illustrates the further over-current reducing arrangement 5b with the associated further breaker 6b. Apparently, over-current-reducing arrangements 5a and 5b will therefore be arranged on either sides of the transformer 1a. It is to be noted that the further breakers 6a and 6b, respectively are positioned in the connections between said over-current reducing arrangements 5a and 5b and the transformer 1a. The further over-current reducing arrangement 5b is intended to protect the transformer 1a from violent current flows towards the transformer from the generator 1b. The circuit breaker 4b will apparently be capable of breaking independently of in which direction between the objects 1a and 1b a safety function is desired.

Fig 20 illustrates diagrammatically how radiant energy may be supplied to the gap between electrodes 23o by means of one or more lasers 25o in one or more spots or areas 28o transversely relative to an axis X of symmetry between the electrodes 23o. By using a plurality of different lasers 25o, a very high power may be supplied to the gap between the electrodes for plasma formation.

Fig 21b illustrates that a plurality of substantially parallel, electrically conducting channels may be formed between the electrodes 23p. The view in fig 21a could be formed by a vertical view of fig 21b, in which case the electrically conducting channels, viewed from the side, is in one single row. However, it is possible to arrange a plurality of electrically conducting plasma channels in not only rows but also columns between the electrodes. The occurrence of a plurality of simultaneously electrically conducting channels increases the conducting capacity of the switch means.

Fig 22 illustrates a variant where the optical system 27q comprises an axicone (refractive or diffractive) dividing the radiation arriving from a laser or similar into parts and directs these radiation parts to diffractive elements (kinoforms 36q). These kinoforms are distributed about one of the electrodes, namely the one denoted 23q in fig 22. The same structure as in fig 22 is shown in perspective in fig 23. It appears in fig 23 that in the example 4 kinoforms 36q are arranged around the electrode 23q to cause the radiant energy to be focused by diffraction in a number of spots or areas 28q present along the axis of symmetry of the electrodes. The use of several discrete kinoforms 36q would appear to be more simple and non-expensive to realize than a continuously angular kinoform even if the latter wouldn't be impossible.

It should be noted that the description presented hereinabove only should be considered as exemplifying for the inventive idea, on which the invention is built. Thus, it is obvious for the men skilled in the art that detailed modifications may be made without leaving the scope of the invention. As an example, it may be mentioned that according to the invention, it is not necessary to use a laser for supply of ionising/plasma forming energy to the gap 24. Also other

radiative sources, for example electron guns, or other energy supply solutions may be applied as long as the rapidness and reliability demands according to the invention are fulfilled. It should be observed that the switch means
5 may according to the invention be applied for protection of electric objects against fault-related over-currents also in other operative cases than the ones illustrated in Figs 1, 3 and 19, where the device according to the invention is arranged in order to reduce the negative effects of the
10 relatively slow breaking time of the circuit breaker 4. Thus, the switch means according to the invention does not necessarily need to be operation-related to such a circuit breaker 4. It should finally be observed that the invention is well suited for alternating current as well as direct
15 current.

Claims

1. A device in an electric power plant for protection of an electric object (1) from fault-related over-currents, characterized in that an over-current reducing arrangement (5), which is actuatable for over-current reduction with assistance of an over-current conditions detecting arrangement (11-13), is connected to the electric power plant for protection of the object, that the over-current reducing arrangement (5) comprises an over-current diverter (7) for diverting over-currents to earth (8) or otherwise another unit having a relatively low potential, that the over-current diverter (7) comprises a switch means (10), which comprises an electrode gap (24), which normally is electrically substantially isolating, and means (25) for causing or at least initiating the electrode gap or at least a part thereof to assume electrical conductivity for diverting over-currents via the electrode gap and said means (25) for causing or at least initiating the electrode gap to assume conductivity are adapted to supply triggering energy to the electrode gap in the form of radiation energy to bring the gap or a part thereof to shape of a plasma by means of said radiation energy.
- 25 2. A device according to any preceding claim, characterized by said means (25) for causing or at least initiating the electrode gap or part thereof to assume electrical conductivity comprising at least one laser (25).
- 30 3. A device according to any preceding claim, characterized in that the switch means (10) is formed in such a way that an electric field is present in its isolating condition between its electrodes (23), which field promotes or generates an electric flash-over between the electrodes on causing or initiating the electrode gap to assume electrical conductivity.
- 35

4. A device according to claim 3, characterized in that the electric field in the isolating condition of the electrode gap (24) has substantially less field strength than the field strength, at which a spontaneous breakthrough takes place.
5. A device according to claim 3 or 4, characterized in that the electric field in the insulating condition of the electrode gap (24) has a field strength which is not more than 30%, suitably not more than 20% and preferably not more than 10% of the field strength, at which a spontaneous breakthrough takes place.
6. A device according to any of the claims 3-5, characterized in that the electric field in the insulating condition of the electrode gap (24) has a field strength which is at least 0,1%, suitably at least 1%, and preferably at least 5%, of the field strength, at which a spontaneous breakthrough takes place.
7. A device according to any preceding claim, characterized in that the means (25) for causing or at least initiating the electrode gap (24) to assume electrical conductivity are arranged to supply the radiant energy in such a manner that the lowest electrical field strength, at which the electrode gap may be triggered to assume electrical conductivity, is minimized.
8. A device according to any preceding claim, characterized in that the means (25) for causing or at least initiating the electrode gap (24) to assume electrical conductivity are arranged to supply the radiant energy to the electrode gap in a such a manner that a time delay between the arriving radiant energy and a developed conductive ability of the electrode gap is minimized.

9. A device according to any preceding claim, characterized in that the switch means (10) and the means (25) for causing or at least initiating the electrode gap to assume electric conductivity are arranged such that the establishment of the electric conductivity in the electrode gap is substantially independent of the electric field strength present between the electrodes of the switch means in its insulating state.
10. A device according to any preceding claim, characterized in that the means (25a, c) for supplying triggering energy to the electrode gap are arranged to apply the radiative energy on or at least in the vicinity of at least one of the electrodes (23).
11. A device according to any preceding claim, characterized in that the means (25b, d) for supplying triggering energy to the electrode gap are arranged to locate the radiative energy in one spot or area in the gap (24b, d) between the electrodes (23b, d).
12. A device according to any preceding claim, characterized in that the members (25, 27e, f, g, h) for supplying the triggering energy to the electrode gap are arranged to apply the radiant energy in two or more spots or areas (28e, f, g, h) between the electrodes.
13. A device according to claim 12, characterized in that the means for supplying triggering energy to electrode gap are arranged to locate said two or more spots or areas of radiant energy along a line extending between the electrodes, said line corresponding to the extent of an electric conduction path desired between the electrodes.
14. A device according to any preceding claim, characterized in that the means (27i, k, m, n) for supplying triggering

energy to the electrode gap are arranged to apply the radiant energy in one or more elongated areas (28i,k, m, n), the longitudinal axes of which extend substantially along the direction of the electric conduction path which is intended between the electrodes.

15. A device according to claim 14, characterized in that the means (27n) for supplying triggering energy to the electrode gap are adapted to shape the elongated focal area into a tubular shape.

16. A device according to claim 14 or 15, characterized in that the means for supplying triggering energy to the electrode gap are adapted to shape the elongated area so that it bridges, entirely or substantially entirely, the space between the electrodes.

17. A device according to any of claims 14 or 15, characterized in that the means (27n) for supplying triggering energy to the electrode gap are adapted to form two or more elongated focal areas (28n, n') in the electrode gap, said focal areas being located longitudinally after each other along the electric conduction path intended between the electrodes.

18. A device according to any of claims 1 and 10, characterized in that the means for supplying triggering energy to the electrode gap are adapted to apply the radiant energy on at least one of the electrodes as well as between them.

19. A device according to any of claims 12, 13 and 17, characterized in that the means (25, 27) for supplying triggering energy to the electrode gap are adapted to apply the radiant energy in said two or more spots or areas with such a time delay between the times for application of the

spots or areas that the propagation of an electrically conducting path between the electrodes is promoted by the successive application of radiant energy in said spots or areas in the direction of propagation.

- 5 20. A device according to any of the claims 10-19, characterized in that at least one of the electrodes at the electrode gap has an opening (29), through which the means (25) for supplying triggering energy are arranged to direct
10 the radiative energy.
21. A device according to claims 15 and 20, characterized in that the means (27n) for supplying triggering energy to the electrode gap are adapted to locate the tubular radiant
15 energy area (28n') in the vicinity of that electrode which has an opening (29n) and such that the axis of the tubular radiant energy area is substantially concentric to the axis of the opening in the electrode.
- 20 22. A device according to any preceding claim, characterized in that auxiliary electrodes (31, 31d) for equalizing the electric field and/or for active participation in the triggering process by said auxiliary electrodes being exposed to the radiant energy and, as a result, being capable of
25 emitting free charges.
23. A device according to any of claims 10-22, characterized in that the means for supplying triggering energy to the electrode gap comprise a system for controlling
30 electromagnetic wave energy.
24. A device according to claim 23, characterized in that the control system comprises at least one refractive, reflective and/or diffractive element.

25. A device according to claim 24, characterized in that the element is formed by an axicone.
26. A device according to claim 24, characterized in that the element is formed by a kinoform.
27. A device according to claim 24, characterized in that the elements comprise optical fibres (38).
28. A device according to any of claims 24-27, characterized in that the control system (27f, h) is located radially outwardly of the electrodes and adapted to direct bunches of rays towards the gap between the electrodes.
29. A device according to any of claims 24-27, characterized in that the control system (27g) is adapted to divide laser pulses into an angular configuration about one of the electrodes.
30. A device according to any preceding claim, characterized in that at least one over-voltage diverter (22) is connected in parallel to the switch means (10).
31. A device according to any preceding claim, wherein the electric object (1) is connected to an electric power network (3) or another equipment included in the electric power plant, the device comprising a switching device (4) in a line (2) between the object and the network/equipment, characterized in that the switch means (10) is connected to the line (2) between the object (1) and the switching device (4), and that the switch means (10) is actuatable for over-current diversion within a time period substantially shorter than the break-time of the switching device (4).
32. A device according to claim 31, characterized in that the switching device (4) is formed by a circuit breaker.

33. A device according to claim 21 or 32, characterized in that it comprises a further breaker (6) arranged in the line between the switching device (4) and the object, said further breaker being arranged between the switching means (10) and the object (1) and being adapted to break lower voltages and currents than the switching device (4) and therefore capable of performing a shorter break-time than the switching device and that the further breaker is adapted to break when the over-current towards or away from the object (1) has been reduced by means of the switch means (10) but substantially earlier than the switching device.

34. A device according to claim 33, characterized in that it comprises a control unit (14) connected to the detecting arrangement (11-13) and to the further breaker (6) in order to achieve actuation of the further breaker for breaking purposes when the over-current towards or away from the object (1) is indicated, by means of the detecting arrangement, to be below a predetermined level.

35. A device according to any of the claims 33-34, characterized in that the further breaker (6) comprises a switch (15) over which there is coupled a shunt line (17) having one or more components (18) for avoiding arcs on separation of contacts of the switch (15) by causing the shuntline (17) to take over current conduction from the contacts.

36. A device according to claim 35, characterized in that said one or more components (18) in the shunt line (17) are closable into conduction by means of control via the control unit (14).

37. A device according to claim 35 or 36, characterized in that said one or more components (18) are formed by controllable semiconductor components.

38. A device according to any of the claims 35-37, characterized in that said one or more components (18) are provided with at least one over-voltage arrester (30).

5

39. A device according to any of the claims 35-38, characterized in that a disconnecter (20) for galvanic separation is arranged in series with said one or more components (18).

10

40. A device according to claim 39, characterized in that the disconnecter (20) is coupled to the control unit (14) to be controlled thereof for opening after the switch (15) having been controlled to have closed and said one or more components (18) having been placed in a condition for breaking the shunt line (17).

15

41. A device according to any preceding claim, characterized in that the protected object (1) is formed by an electric apparatus with a magnetic circuit.

20

42. A device according to claim 41, characterized in that the object is formed by a generator, transformer or motor.

25

43. A device according to any of the claims 1-42, characterized in that the object is formed by a power line, e.g. a cable.

30

44. A device according to any preceding claim, characterized in that two switch means (10) are arranged on either sides of the object to protect the same from two sides.

35

45. A device according to claim 1, characterized in that it comprises a control unit (14) connected to the switch means (10) and to the over-current conditions detecting arrangements (11-13), said control unit (14) being arranged to control the switch means to closing based upon information from

the over-current conditions detecting arrangement when required for reasons of protection.

46. A device according to claim 45 and one or more of the
5 claims 34, 36 and 40, characterized in that one and the same
control unit (14) is arranged to control, based upon information from the over-current conditions detecting arrangement (11-13), the switch means (10) and the further breaker
10 (6).

47. Use of a device according to any preceding claim for protection of an object against fault-related over-currents.

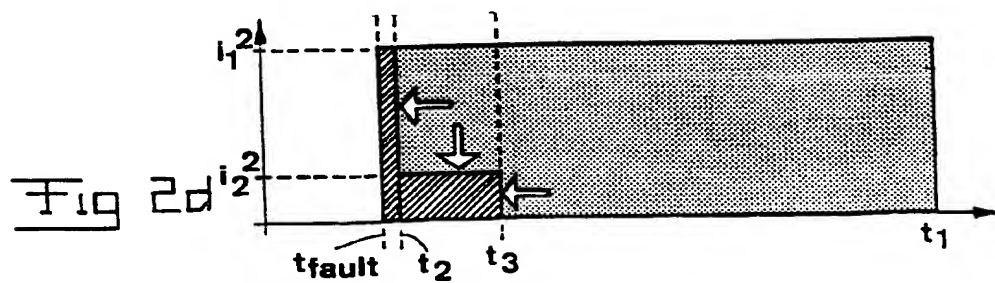
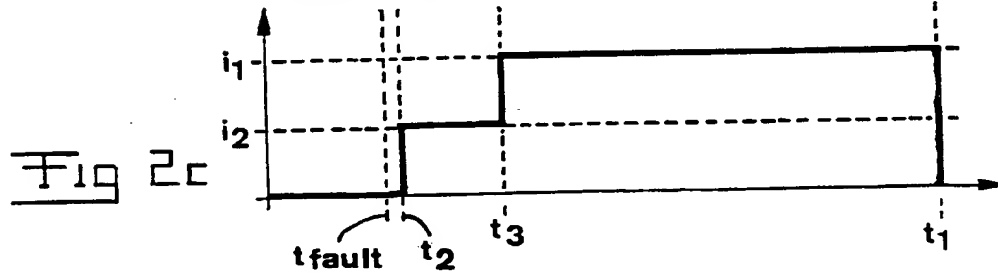
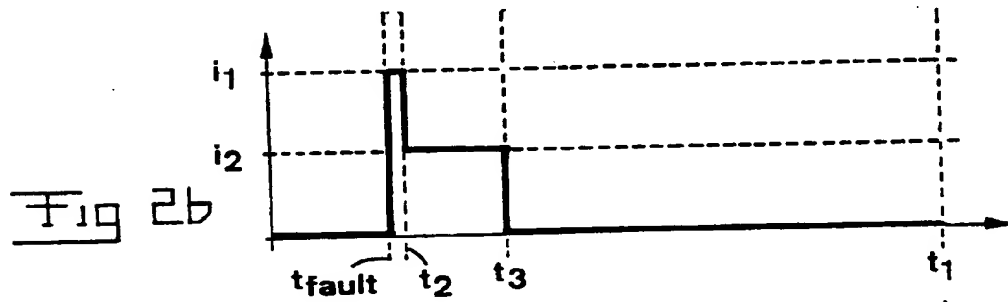
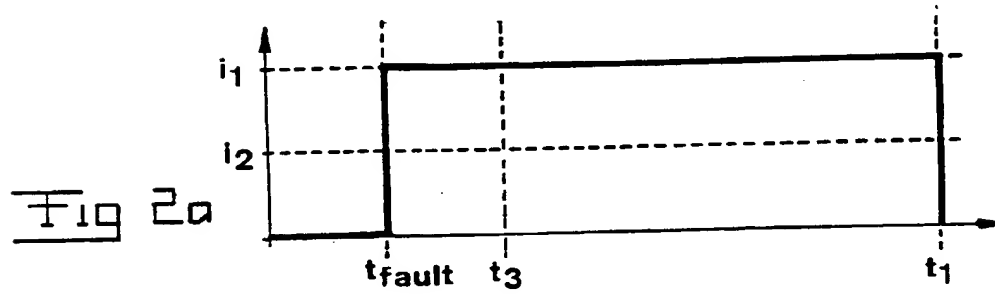
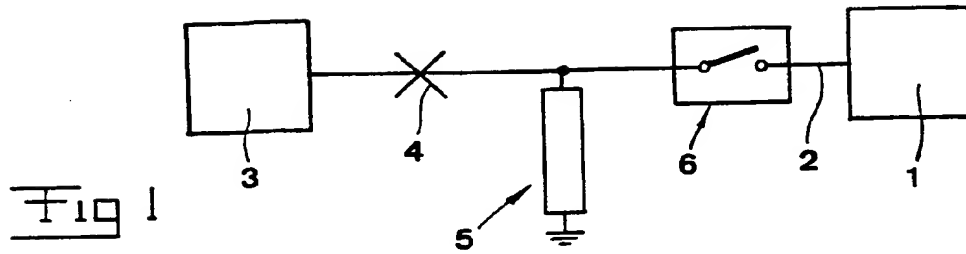
48. A device according to any preceding claim, characterized
15 in that the means for supplying triggering energy to the electrode gap are adapted to focus the radiant energy in a plurality of substantially parallel, elongated focal areas, the longitudinal axes of which are located substantially along the direction of the electrical conduction path aimed
20 at between the electrodes (fig 21).

49. A method in an electric power plant for protection of an electric object (1) from fault-related over-currents, characterized
25 means of a switch means (10) when over-current conditions have been detected by means of an arrangement (11-13) for such detection, said switch means (10), which is arranged for diversion of over-currents to earth (8) or some other unit with a relatively low potential, being closed for over-current diversion by imparting an electrode gap (24), which
30 is present in the switch means, electrical conductivity by supply of radiant energy to the electrode gap with the aid of triggering means (25).

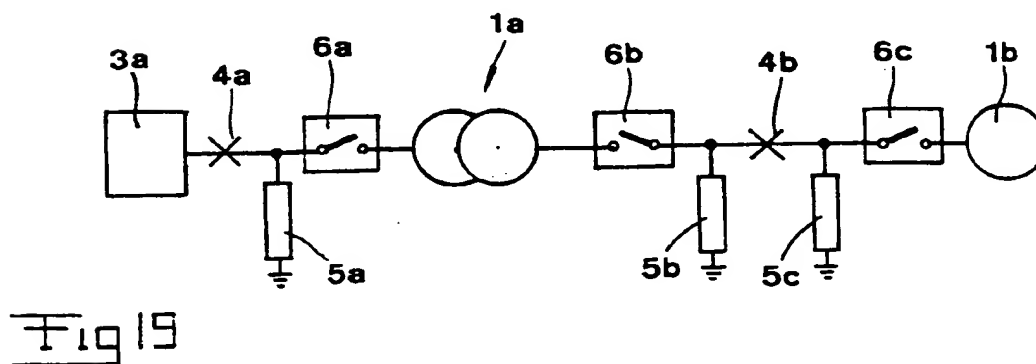
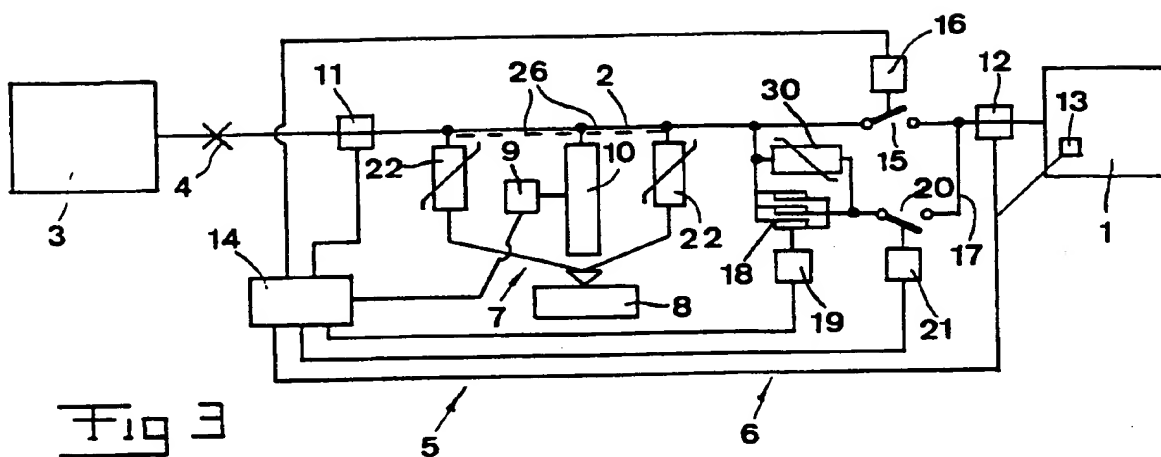
50. A method according to claim 49, characterized in that a
35 further breaker (6), which is arranged in a line (2) between

a switching device (4) and the object (1) and between the switch means (10) and the object (1), is actuated for breaking after the over-current towards or away from the object (1) having been reduced by means of the switch means (10).

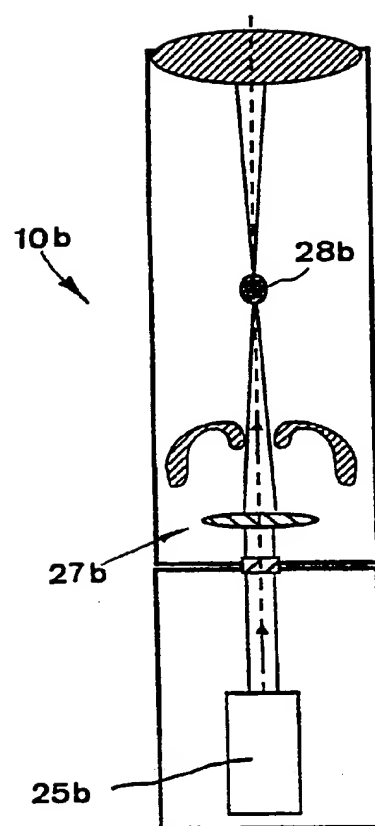
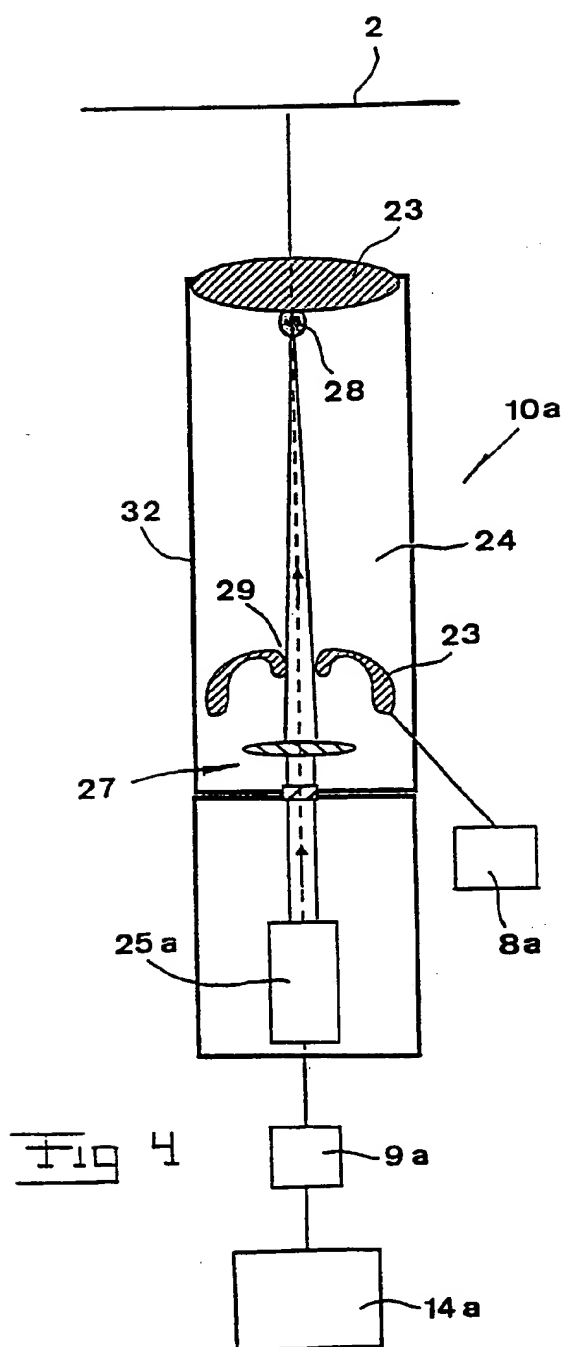
1 / 8



2 / 8



3 / 8



4 / 8

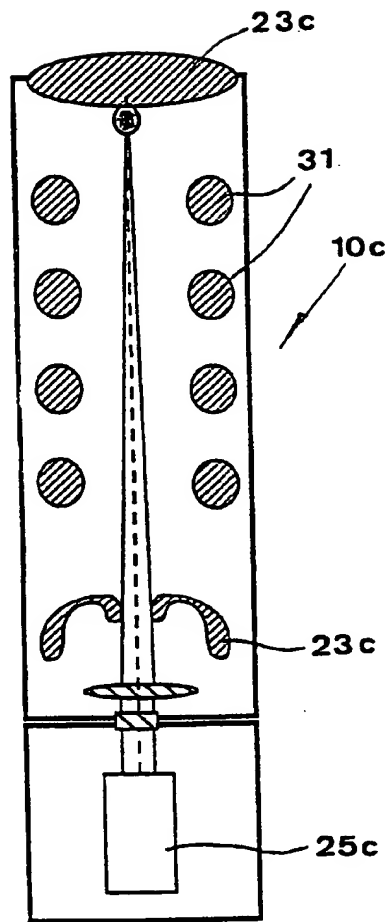


Fig 6

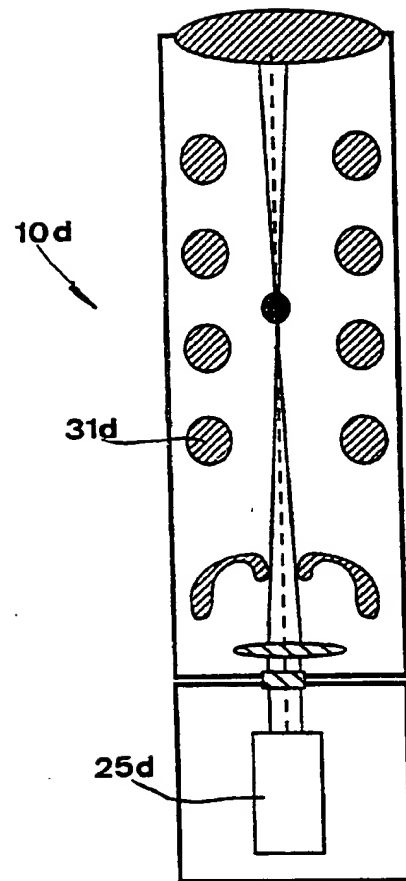
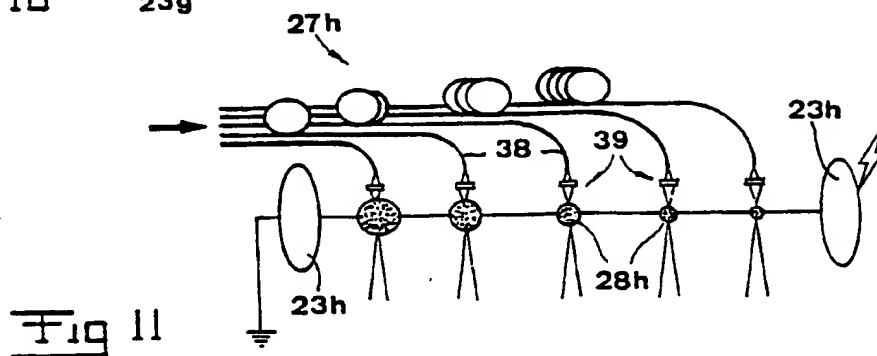
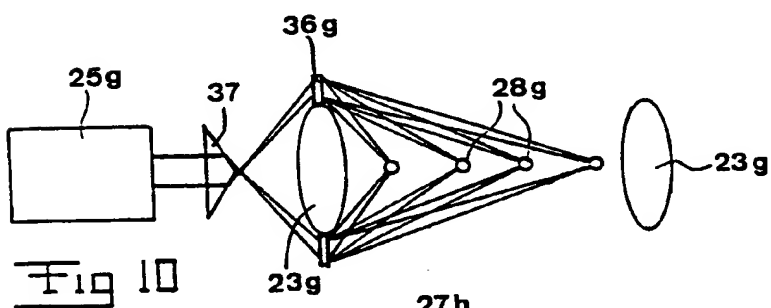
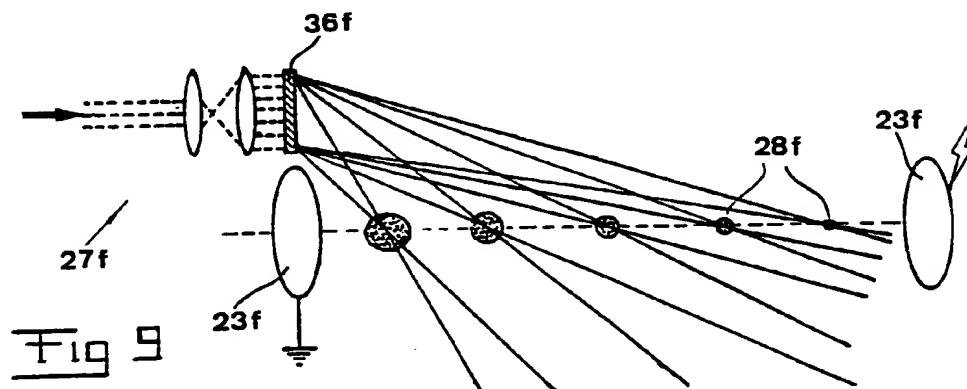
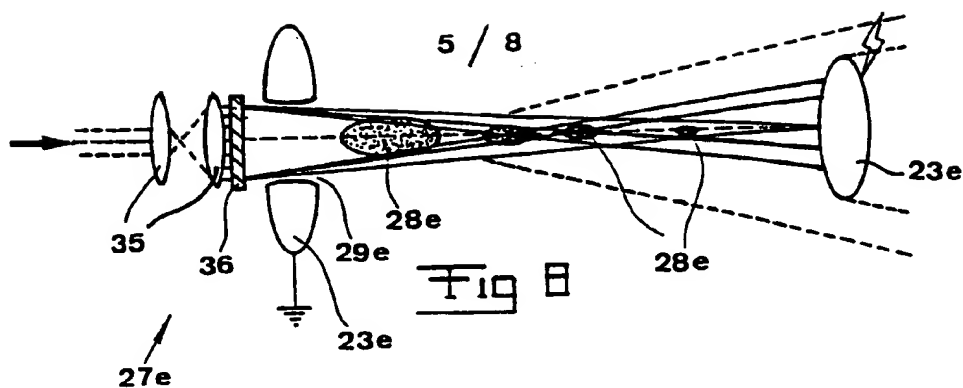
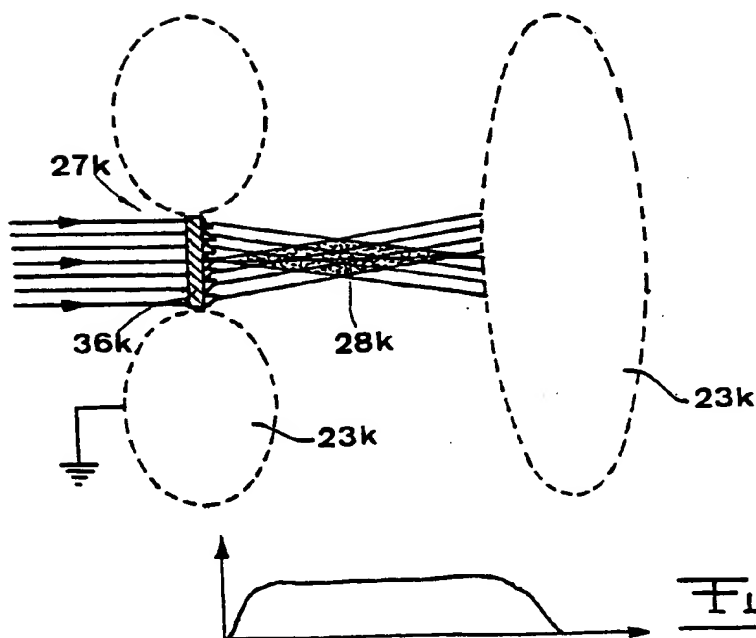
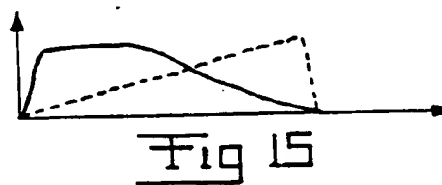
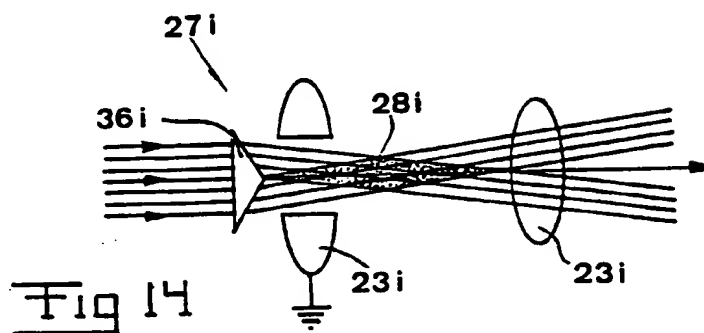
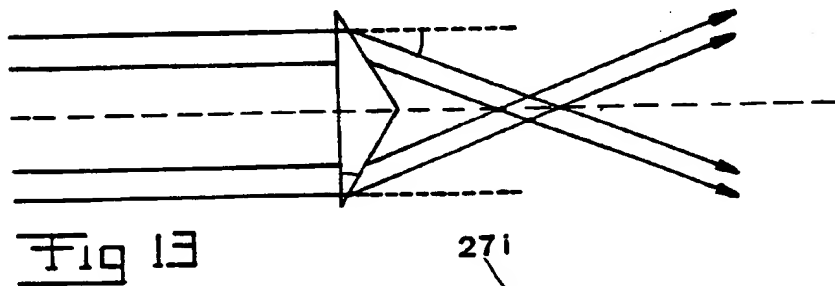
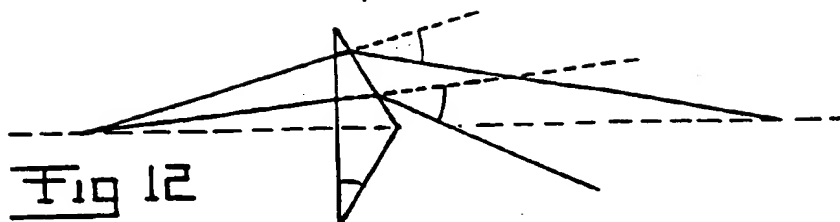


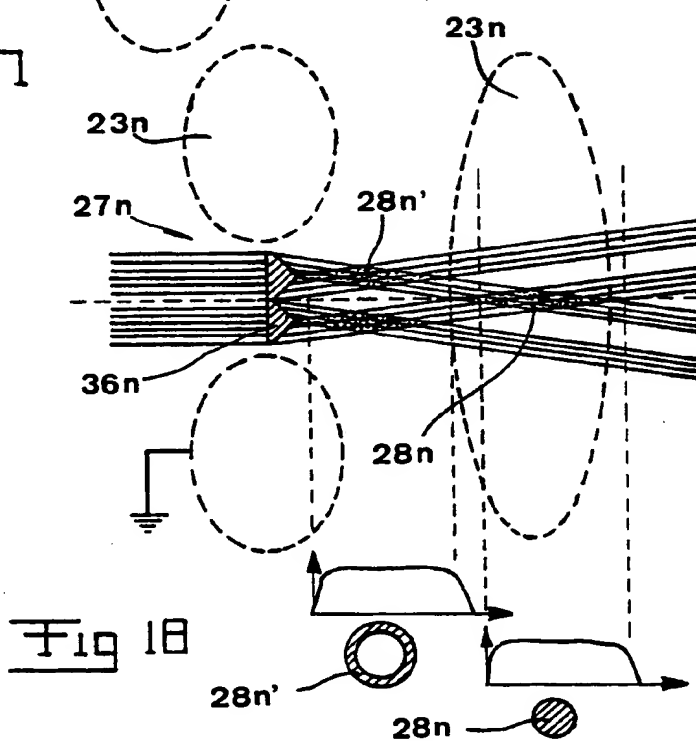
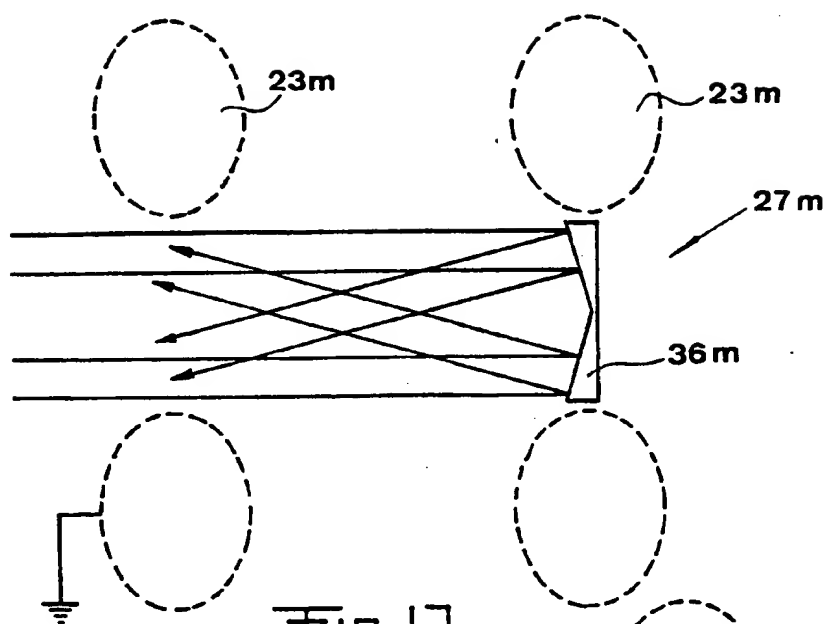
Fig 7



6 / 8



7 / 8



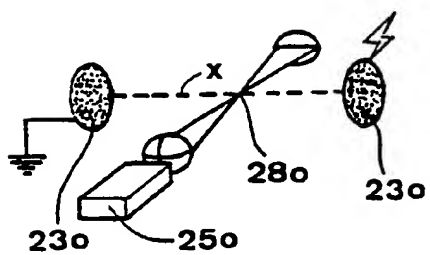


Fig 20a

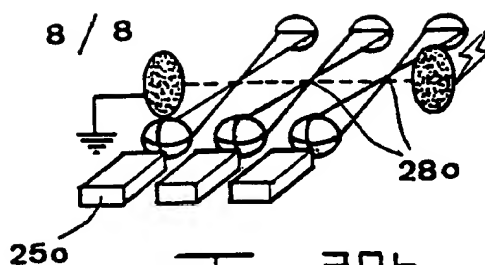


Fig 20b

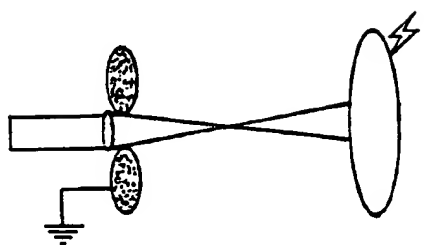


Fig 21a

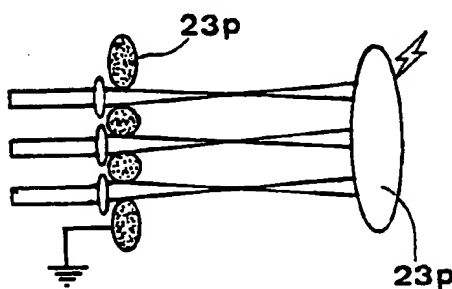


Fig 21b

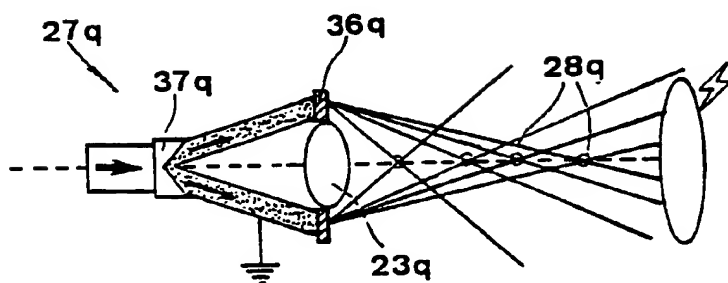


Fig 22

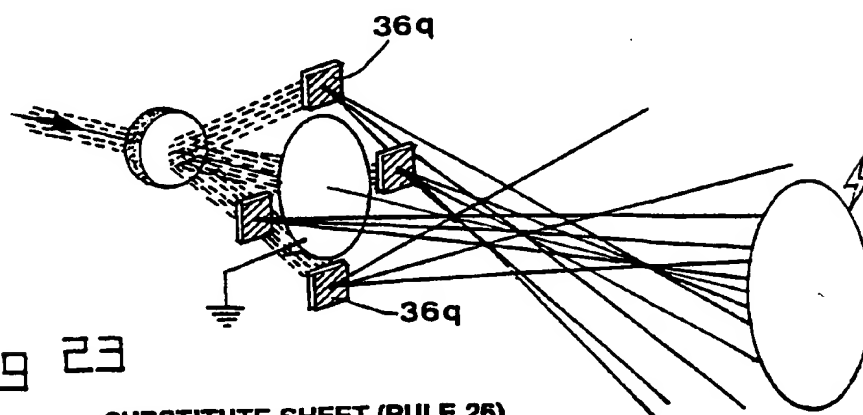


Fig 23

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

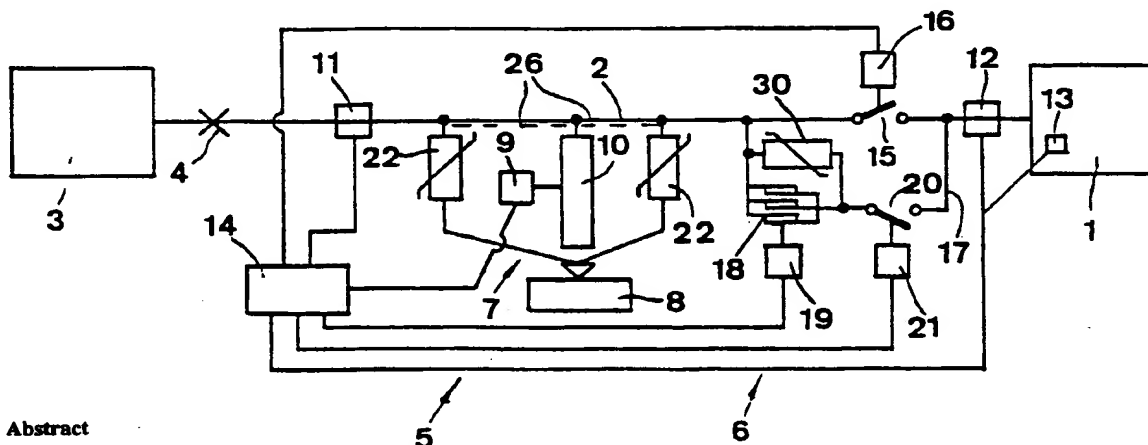


8379
15 R

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification n 6: H02H 9/02, H01T 2/00		A3	(11) International Publication Number: WO 98/29931
			(43) International Publication Date: 9 July 1998 (09.07.98)
(21) International Application Number: PCT/SE97/02131		(74) Agents: BJERKÉN, Håkan et al.; Bjerkéns Patentbyrå KB, P.O. Box 1274, S-801 37 Gävle (SE).	
(22) International Filing Date: 17 December 1997 (17.12.97)			
(30) Priority Data: 9604631-3 17 December 1996 (17.12.96) SE		(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, FI (Utility model), GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).	
(71) Applicant (for all designated States except US): ASEA BROWN BOVERI AB [SE/SE]; S-721 78 Västerås (SE).			
(72) Inventors; and			
(75) Inventors/Applicants (for US only): BERGQVIST, Mikael [SE/SE]; Champinjonvägen 8, S-756 45 Uppsala (SE). BERNHOFF, Hans [SE/SE]; Limsta, Geddeholm, S-720 02 Västerås (SE). EKBERG, Mats [SE/SE]; Brunnbjörnsvägen 56, S-722 42 Västerås (SE). FOGELBERG, Thomas [SE/SE]; Bergsmansgatan 12, S-771 35 Ludvika (SE). ISBERG, Jan [SE/SE]; Karlsgatan 27, S-722 14 Västerås (SE). LEIJON, Mats [SE/SE]; Hyvlargatan 5, S-723 35 Västerås (SE). MING, Li [CN/SE]; Högbys Skogsväg 1, S-723 41 Västerås (SE). SUNESSON, Anders [SE/SE]; Hvilans Allé 6, S-232 51 Åkarp (SE). WINDMAR, Dan [SE/SE]; Smedstorpet 18, S-744 95 Vittinge (SE). RUSSBERG, Gunnar [SE/SE]; Förvaltargatan 12, S-724 66 Västerås (SE).		Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments. In English translation (filed in Swedish).	
		(88) Date of publication of the international search report: 13 August 1998 (13.08.98)	

(54) Title: A DEVICE AND A METHOD FOR PROTECTING AN OBJECT AGAINST FAULT RELATED OVER-CURRENTS, AND ITS USE



(57) Abstract

This invention is related to a device and a method in an electric power plant for protection of an object (1) against over-currents from a network (3) or another equipment included in the high voltage plant, the device comprising a switching device (4) in a line (2) between the object and the network/equipment. The line (2) between the object and the network/equipment is connected to an arrangement (5) reducing over-currents towards the object (1), said arrangement (5) being actuatable for over-current reduction with the assistance of an over-current condition detecting arrangement (11-13) within a time period substantially less than the break-time of the switching device (4). The over-current reducing arrangement (5) comprises a switch means (10) with an electrode gap, which may be imparted electrical conductivity for over-current diversion.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
ER	Estonia						

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 97/02131

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02H 9/02, H01T 2/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02H, H01H, H01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3418530 A1 (W.H. CHEEVER), 24 December 1968 (24.12.68), column 1, line 45 - line 72; column 2, line 1 - line 15; column 2, line 65 - line 71, figures 1,2 --	1-30,48
Y	US 5153460 A (L.J. BOVINO ET AL.), 6 October 1992 (06.10.92), column 1, line 14 - line 31; column 1, line 47 - line 54; column 2, line 21 - line 29, ; column 3, line 36 - line 42; column 3, line 49 - line 60, figure 2, abstract --	1-6,8,30-34, 41-47,49-50
Y	DE 4426594 A1 (FUJI ELECTRIC CO., LTD.), 2 February 1995 (02.02.95), column 7, line 32 - line 51; column 10, line 18 - line 21, abstract --	7,9

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 June 1998

Date of mailing of the international search report

25-06-1998

Name and mailing address of the ISA/
Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Hans Bagge af Berga
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 97/02131

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Patent Abstracts of Japan, abstract of JP 81-67360 A (TOSHIBA CORP), 31 October 1996 (31.10.96), see the whole document and the figure --	1-4,10-21, 23-26,30-34, 41-47,49-50
Y	US 4978893 A (P.J. BRANNON ET AL.), 18 December 1990 (18.12.90), column 1, line 10 - line 12; column 2, line 35 - line 43; column 3, line 18 - line 29, ; column 4, line 28 - line 51 --	1-4,10, 14-16,18, 20-24,30-34, 41-47,49-50
Y	US 5399941 A1 (M.G. GROTHAUS ET AL.), 21 March 1995 (21.03.95), column 1, line 10 - line 15; column 3, line 8 - line 28; column 3, line 39 - line 55, ; column 4, line 20 - line 35; column 4, line 46 - line 54; figures 2-5, abstract --	1-4,10-16, 20-21,23-24, 27,29,30-34, 41-50
Y	US 4484106 A (R.S.TAYLOR ET AL.), 20 November 1984 (20.11.84), column 2, line 10 - line 16; column 2, line 26 - line 38; column 4, line 21 - line 30, ; column 5, line 7 - line 14; column 5, line 32 - line 44; column 6, line 41 - line 46, figure 11 --	1-4,10-12, 23-24,28, 30-34,41-47, 49-50
Y	US 4184186 A1 (P. BARKAN), 15 January 1980 (15.01.80), column 1, line 60 - line 62; column 2, line 16 - line 29; column 2, line 44 - line 51, ; column 4-6; column 7, line 55 - line 61, figures 1,2 --	1,31-34, 41-47,49-50
A	US 4134146 A1 (E.W. STETSON), 9 January 1979 (09.01.79), column 1, line 1 - line 14 -- -----	30

INTERNATIONAL SEARCH REPORT

Information on patent family members

09/06/98

International application No.

PCT/SE 97/02131

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
US	3418530	A1	24/12/68	NONE		
US	5153460	A	06/10/92	NONE		
DE	4426594	A1	02/02/95	JP	7045205 A	14/02/95
				US	5631524 A	20/05/97
US	4978893	A	18/12/90	NONE		
US	5399941	A1	21/03/95	NONE		
US	4484106	A	20/11/84	CA	1222788 A	09/06/87
US	4184186	A1	15/01/80	NONE		
US	4134146	A1	09/01/79	CA	1121443 A	06/04/82

THIS PAGE BLANK (USPTO)